NASA Innovative Advanced Concepts

Exploration Architecture with Quantum Inertial Gravimetry and In Situ ChipSat Sensors

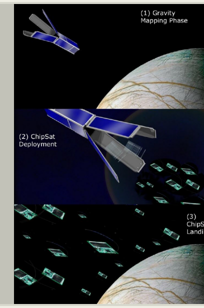
Completed Technology Project (2014 - 2015)

Project Introduction

We propose to break the two-mission space exploration cycle (remote survey eventually followed by in situ sensing) by creating mission architectures that perform both remote survey and in situ sampling. Through enabling technologies, such as high-accuracy quantum, or cold-atom, inertial sensors based on light-pulse atom interferometry (LPAI), and the extreme miniaturization of space components into fully functional spacecraft-on-a-chip systems (ChipSats), these combined missions can perform decadal-class science with greatly reduced time scales and risk.

Anticipated Benefits

Adoption of dual exploration architectures may short circuit the long, slow cycle of missions to inaccessible bodies by eliminating the need for separate precursor and follow-up missions. Additionally, the dual architecture possesses inherent flexibility that enables the design of adaptive, event-driven missions that are very different from traditional, largely pre-planned missions. A survey of historical and current missions finds that opportunities for exploration are becoming less frequent, causing the flexibility and dual-nature elements of each mission to become more common. The dual exploration architecture takes these trends to their far conclusion, attempting to eliminate precursor and follow-up missions while still returning more scientific payoff. A study of the future of planetary science goals through the decadal survey reveals broad applicability of dual missions to solve mysteries that cannot be answered with a traditional mission architecture. These missions fall into three broad classes: choosing a local target from a global survey, dynamic/reactive science, and global in-situ networks.



Technology concept diagram

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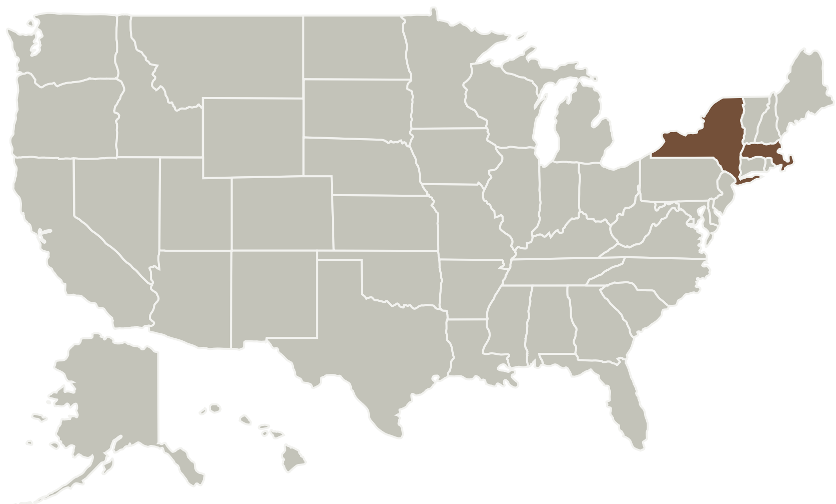
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
The Charles Stark Draper Laboratory, Inc.	Lead Organization	R&D Center	Cambridge, Massachusetts
Cornell University	Supporting Organization	Academia	Ithaca, New York

Primary U.S. Work Locations	
Massachusetts	New York

Project Transitions

July 2014: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

The Charles Stark Draper Laboratory, Inc.

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

Eric A Eberly

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Brett Streetman

Co-Investigators:

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Mason A Peck
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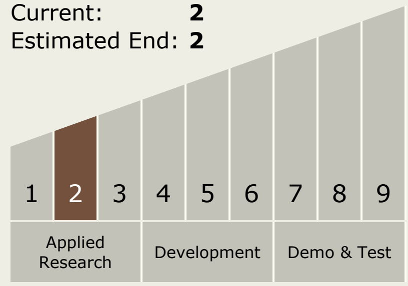
July 2015: Closed out

Closeout Summary: The Dual Exploration Architecture is a mission concept that combines remote sensing and in-situ observations into a single mission to answer planetary science questions that can only be answered with both types of data. Adoption of dual exploration architectures may short circuit the long, slow cycle of missions to inaccessible bodies by eliminating the need for separate precursor and follow-up missions. Additionally, the dual architecture possesses inherent flexibility that enables the design of adaptive, event-driven missions that are very different from traditional, largely pre-planned missions. Five key observations about the state and trends of planetary science exploration lead us to the dual architecture: increasing complexity of observations, scarcity of future mission opportunities, desire to capture transitory events, continued miniaturization of spacecraft components, and the Mars exploration cycle. Our goal in this study is to explore missions that can only happen using the dual architecture concept and find technology development needs that must be filled for those missions to compete. A survey of historical and current missions finds that opportunities for exploration are becoming less frequent, causing the flexibility and dual-nature elements of each mission to become more common. The dual exploration architecture takes these trends to their far conclusion, attempting to eliminate precursor and follow-up missions while still returning more scientific payoff. A study of the future of planetary science goals through the decadal survey reveals broad applicability of dual missions to solve mysteries that cannot be answered with a traditional mission architecture. These missions fall into three broad classes: choosing a local target from a global survey, dynamic/reactive science, and global in-situ networks. Two example missions of each class are notionally described. A deeper look at these dual architecture classes reveals four technology development needs that must be addressed for wide adoption of dual missions: passive landers, guided atmospheric probes, robust sensing packages, and small, precise orbital instruments. This study pursues a specific focus on two examples of such enabling technologies: the ChipSat and cold atom gravimetry. The ChipSat is a fully functional spacecraft-on-a-chip system that has broad versatility in the dual architecture mission space. Initial studies show that ChipSats could survive as passive impactor landers on bodies up to the size of Europa. Furthermore, COTS components could provide an in-situ senor suite that readily answers a number of pressing planetary science questions. Cold atom gravimetry uses inertial sensors based on light-pulse atom interferometry in a small form factor to map the gravity field of a body to precision equaling what would normally require two full spacecraft to achieve. The cold atom gravimeter provides an example of how advanced remote sensing capability can enable dual missions by providing greater returns in a significantly smaller package. Using the above two technologies, we study an example dual architecture mission to both characterize and sample the subsurface oceans at Europa. The greatest scientific return in terms of detecting extraterrestrial life is in those regions where Europa's ice crust is thin. The identification of regions with thin ice should therefore precede the selection of surface targets and dispatch of probes to those targets. This two-step process, if accomplished by separate flagship-scale missions, might take decades. As a result, a combined mission to both identify thin areas of Europa's ice and follow up with surface observations at those regions is a good candidate for the dual exploration architecture. This example mission consists of an orbiter spacecraft carrying a cold atom gravimeter capable of sensing or inferring the ice thickness on regional to local scales, along with a number of ChipSat probes capable of landing on the moon. The small size and weight of the ChipSats allows large numbers of them to be carried, ensuring that enough can be dropped to ensure survival of a minimum numbe

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **2**



Technology Areas

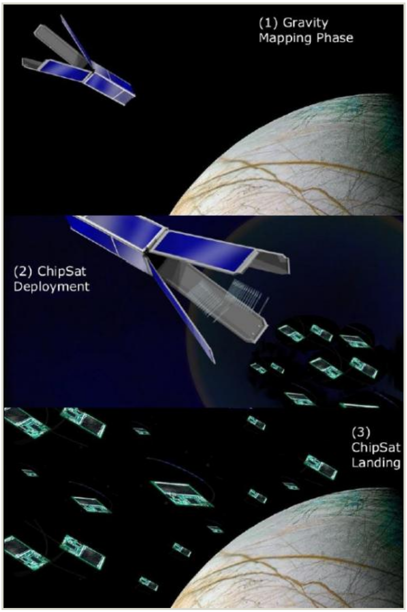
Primary:

- TX04 Robotic Systems
  - └ TX04.3 Manipulation
    - └ TX04.3.4 Sample Acquisition and Handling

Target Destination

Others Inside the Solar System

Images



Exploration Architecture with Quantum Inertial Gravimetry and In Situ ChipSat Sensors Concept
Technology concept diagram
(https://techport.nasa.gov/image/102253)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html